Nov. 10, 1970 D. W. PAYNE 3,540,041

FIRE WARNING SYSTEM IMPROVEMENT

Filed July 24, 1967 3 Sheets-Sheet 1

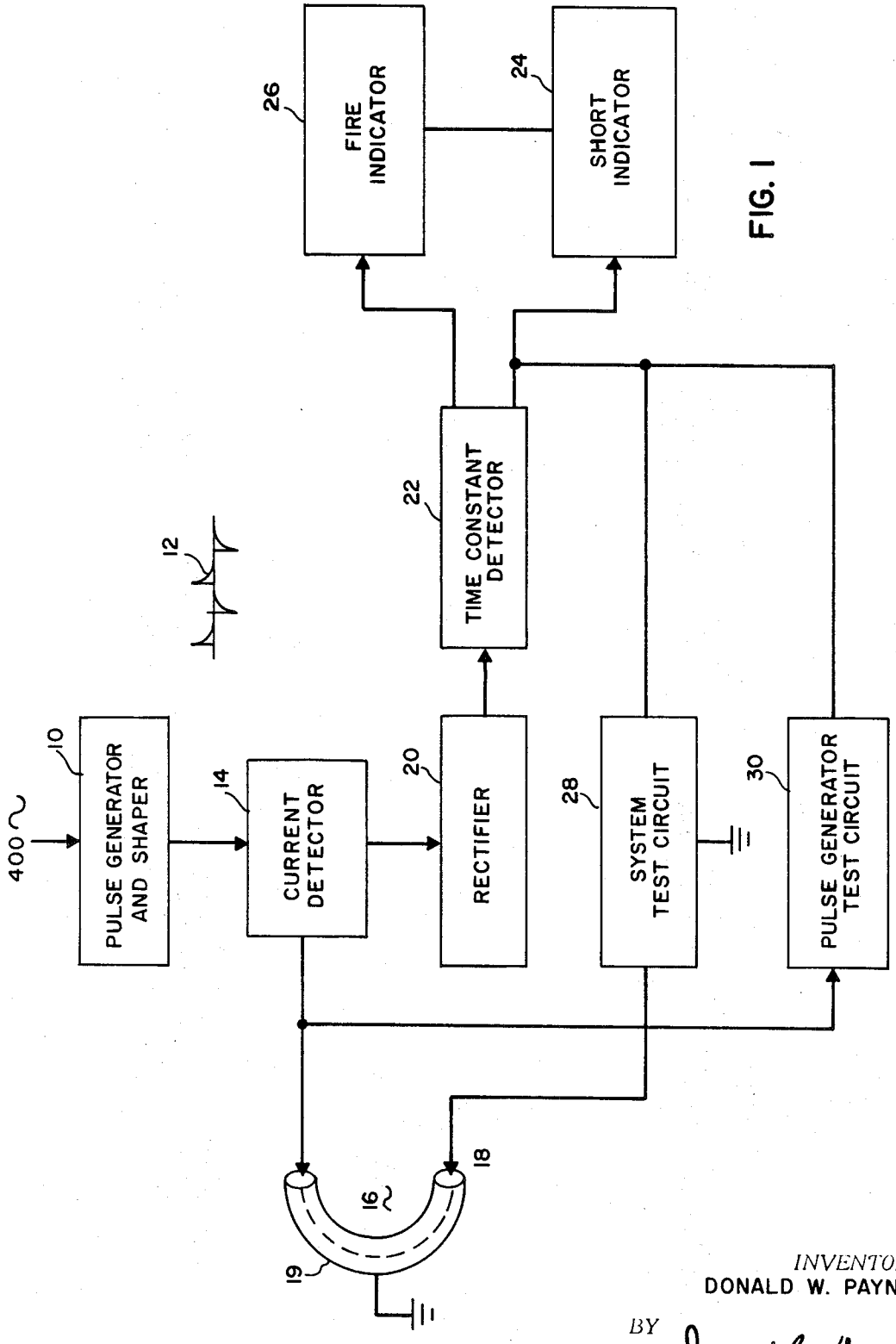

FIG. 1

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Nov. 10, 1970 D. W. PAYNE 3,540,041

FIRE WARNING SYSTEM IMPROVEMENT

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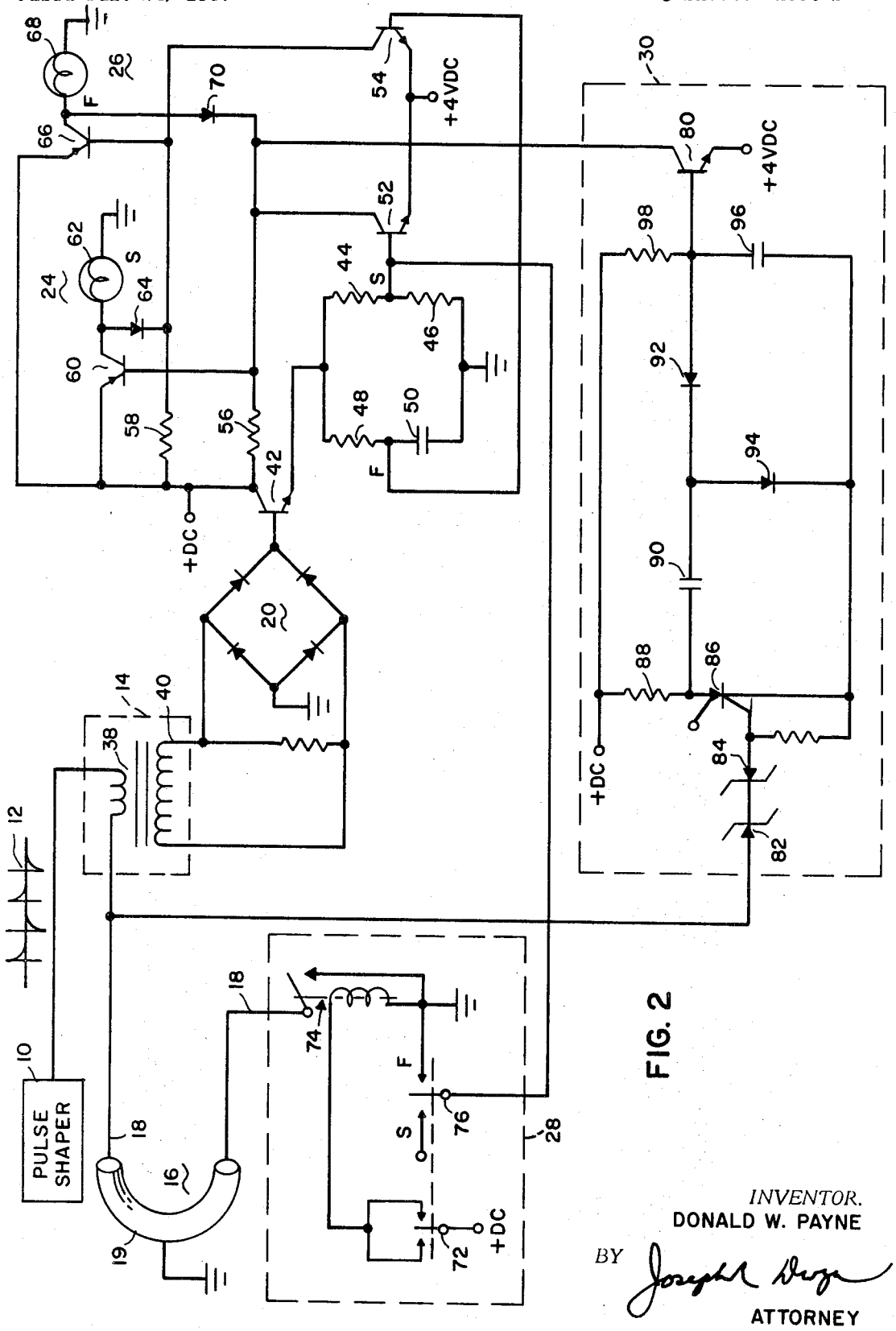

FIG. 2

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FIRE WARNING SYSTEM IMPROVEMENT

Filed July 24, 1967 3 Sheets-Sheet 3

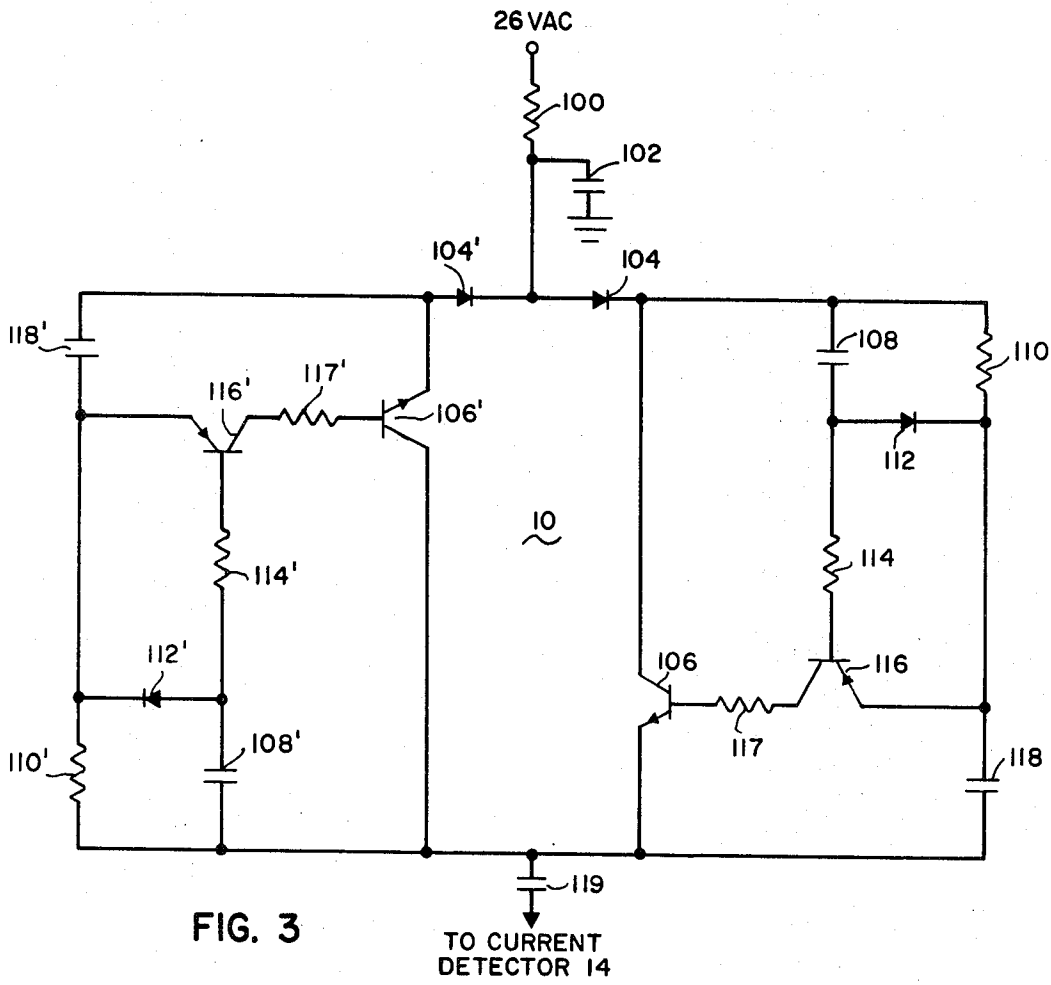

FIG. 3

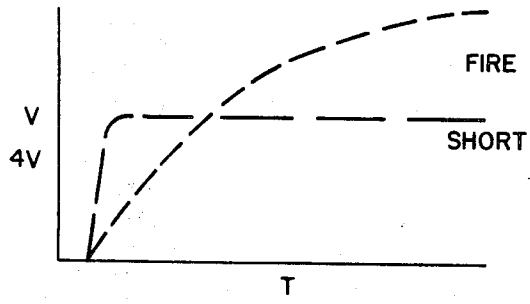

FIG. 4

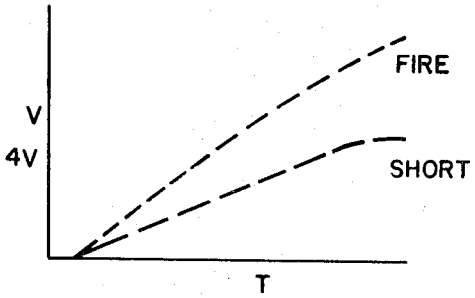

FIG. 5

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United States Patent Office 3,540,041
Patented Nov. 10, 1970

3,540,041

FIRE WARNING SYSTEM IMPROVEMENT

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Filed July 24, 1967, Ser. No. 655,446
Int. Cl. G08b 17/06, 29/00
U.S. Cl. 340—409 7 Claims

ABSTRACT OF THE DISCLOSURE

An electronic system which, when coupled to a eutectic salt heat sensor as used in aircraft, will not only provide an indication of excessive heat but will also distinguish between excessive heat and a malfunction of the heat sensor. A continuous train of electrical pulses is applied through a current sensor to the heat sensor. If a physical fault is developing in the eutectic salt, the pulses will generally cure the fault; however, if the salt sensor is overheating or if an incurable fault exists, thus reducing the impedance of the salt, the current sensor detects the current increase in the pulse train and applies a signal to circuitry which, by determination of the current change rate, distinguishes between a malfunction or a true overheating condition. Further reliability of the system is improved by various test circuits which provide indications of malfunction of the pulse train generator and the various indicator circuits.

BACKGROUND OF THE INVENTION

Large commercial aircraft must carry fire warning systems which will alert the pilot of the impending danger so that appropriate safety measures may be taken to avert disaster. These fire warning systems generally include one or more heat sensors attached directly to the engines and other sensitive components of the aircraft. A heat sensor is generally in the form of a tubular electrically conductive element with a centrally located coaxial conductor separated from the outer tube with a eutectic salt. Under normal conditions, the eutectic salt has a very high resistance and provides effective insulation between the center conductor and the outer tubing; however, when the salt is subjected to a high heat, its internal structure gradually breaks down and its impedance is reduced to a low value. Nearly all present day fire warning systems operate by measuring the impedance between the center conductor and the outside tubing of such a eutectic salt heat sensor.

The eutectic salt heat sensor is extremely reliable in detecting the existence of fire or overheating. It is, however, unreliable in that it often indicates the existence of a fire when none, in fact, exists. It has been discovered that small physical fractures, or faults, will develop in the eutectic salt from shock or vibration and such fractures will cause instantaneous short circuits between the inner conductor and the outer tubing of the heat sensor. When such a false indication of fire is transmitted through a fire warning system to the aircraft crew, it is mandatory that emergency action be taken and, since fire extinguishing action will not turn off the false fire indication, the aircraft may be forced to make an emergency landing. It is apparent that such emergency action results in great loss of time and increased operating expense.

As disclosed in copending application Ser. No. 481,849 filed Aug. 23, 1965, a system has been discovered which cannot only distinguish between a true fire and a fractured heat sensor, but which can also cure or heal many of the fractures which develop in the eutectic salt during flight.

It has been found that the heating of the eutectic salt due to a fire will result in a gradual decrease in resistance between the center conductor and the outside tubing of the sensor. A short circuit through the salt caused by a fault or fracture will result in a nearly instantaneous drop in resistance. The copending application discloses a fire warning system that operates by measuring the time required for the resistance to reach its fullest value. When the resistance drops, either by fire or by fracture, a series of electrical pulses are applied to the center conductor. These pulses will, in many cases, fuse together a fracture in the salt to restore the normal insulation resistance of the salt. If this train of electrical pulses is applied to a sensor which is detecting an actual fire, the resistance of the salt will be unaffected and the fire indicator will continue to operate.

A difficulty encountered with the fire warning system disclosed in the copending application is that not all of the actual faults can be cured by the application of the electrical pulses. It has now been discovered that some faults that occur in the eutectic salt are polarized, so that an electric pulse of one polarity will not cure the fault whereas a pulse of the opposite polarity will cure it. Furthermore, in the prior system, an actual fault had to occur and thus produce a low resistance before the train of healing pulses were applied to the sensor. In the present system, a continuous train of electrical pulses of both polarities are applied to the sensor to cure fractures as they develop.

BRIEF DESCRIPTION OF THE INVENTION

The invention comprises circuitry which is coupled to a eutectic salt type of fire sensor, and includes an electric pulse former and shaper which supplies a continuous train of both positive and negative pulses through a current detector to the sensor; for both curing fractures in the salt which would cause a rapid short circuit between the two coaxial conductors of the sensor; and also for detecting a current flow caused by the reduced resistance in the salt by overheating. The current detector, sensing a current flow into the fire sensor, generates an electrical signal which is rectified and transmitted to a time constant detector. If the rectified signal received by the time constant detector rapidly increases in amplitude, a short circuit indicator is activated; however, if the rectified signal slowly increases in amplitude, the fire warning indicator will be activated. The invention also includes test circuitry which continuously monitors the output of the pulse generator and shaper to provide a malfunction indication, and further includes test circuitry which may be manually activated to test the entire fire warning circuitry and its associated output indicators.

DESCRIPTION OF THE DRAWINGS

In the drawings which illustrate a preferred embodiment of the invention:

FIG. 1 is a block diagram of the circuitry which incorporates the fire warning circuits and various test circuits of the invention;

FIG. 2 is a schematic diagram of the circuitry displayed in block form in FIG. 1;

FIG. 3 is a schematic diagram of the pulse generator and shaper circuitry;

FIG. 4 is a graph illustrating response characteristics when the time constant detector senses a short circuit signal from the current detector; and

FIG. 5 is a graph of the response characteristic of the time constant detector when the current detector senses an indication of "fire."

In FIG. 1 which shows a general arrangement of the various circuits in block form, pulse generator **10** is connected to an alternating current source, which is prefer-

ably 400 cycles, and produces a continuous train of pulses **12** of both positive and negative polarity and having a repetition rate corresponding to the frequency of the alternating current source. Each of the pulses has a sharp rise time and, as will be hereinafter explained, are produced by the discharge of capacitors. The train of pulses **12** is applied through a current detector **14** to a fire sensor **16** which, as previously noted, normally comprises an electrical conductor **18** which is centrally positioned within and insulated from a coaxial tubular conductor **19** by a eutectic salt which lowers in resistance when subjected to such a heat that is produced by a fire in the engine or other component to which a fire sensor **16** is attached. Thus, under normal operating conditions, the train of pulses **12** would be transmitted to the center conductor **18** and, since an extremely high resistance exists between conductor **18** and the ground potential of the outer tubular element **19** of the fire sensor **16**, no current flow would be sensed by the current detector **14**. If, however, the eutectic salt in the fire sensor **16** lowered in resistance either by sensing a fire or through a fracture in the structure of the salt, current detector **14** would detect this current flow and transmit a signal to rectifier **20** and the resulting direct current signal to time constant detector **22**.

It has been found that eutectic salt in a typical fire sensor will display a lower resistance due to a fracture in the lattice structure of the salt itself. Similarly, it has also been discovered that the application of a current pulse having a sharp rise time will, in most cases, fuse a fracture and restore the eutectic salt to its normally high resistance characteristics. It has further been discovered that a low resistance fracture in the eutectic salt may be polarized so that a current pulse of one polarity will not cure the fault whereas a current pulse of the opposite polarity will restore the salt to its normal high resistance. Thus, the train of pulses **12** applied to the center conductor **18** of the fire sensor **16**, will not only provide current detector **14** with a signal indicating a fire, but will also provide a continuous source of bipolar fracture healing pulses **12** to the eutectic salt and will thereby prevent the occurrence of any fractures before they actually occur from shock or vibration. In the event that a fracture occurs that cannot be cured by the train of pulses **12**, the eutectic salt will display a very rapid decrease in resistance. On the other hand, if a fire is detected by a fire sensor **16**, there will be a gradual decrease in resistance. Time constant detector **22** discriminates between the fast current rise produced by a short circuit in the fire sensor **16** and the slow current rise that is typical of a fire sensed by the sensor **16** and applies excitation to either the "short" indicator **24** or the "fire" indicator **26**.

In any fire warning system there is a continual danger that the system circuitry itself will fail so that an actual fire will remain undetected until a disaster occurs. System test circuit **28**, which may be activated at the convenience of the aircraft crew, tests the operability of the fire warning system by grounding center conductor **18** of the fire sensor **16** so that the circuitry will sense an apparent fire or short circuit in the fire sensor **16**. The sudden current sensed by current detector **14** will register as a short circuit on "short" indicator **24** if the circuitry is functioning properly. In order to test the operability of the "fire" indicator **26**, the system test circuit **28** may be activated to ground or block the "short" indicator **24** so that fire indicator **26** will become activated. Thus, at the discretion of the aircraft crew, the entire fire warning circuitry, including both "short" indicator **24** and "fire" indicator **26**, may be tested by the application of a false short circuit to the fire sensor **16**.

An additional safety feature is provided by pulse generator test circuit **30** which samples the pulses **12** as they are applied to the center conductor **18** of the fire sensor **16** and provides an indication on short indicator **24** in the event of an AC power failure or circuit failure in the pulse generator and shaper **10**.

FIG. 2 schematically illustrates circuitry for implementing the block diagram of FIG. 1. Pulse shaper **10** which will hereinafter be explained in detail supplies a steep wavefront pulse of both polarities through current detector **14** to the center conductor **18** of fire sensor **16**. Current detector **14** is comprised of a current transformer which may have a pimary to secondary turns ratio of 2:36. Seconday terminals **40** of the current transformer are connected to the input terminals of rectifier **20** which may consist of four diodes connected in a standard bridge rectifier configuration. The negative output terminal of rectifier **20** is connected to ground and the positive output terminal is coupled to the base of an NPN transistor **42** which functions as a power amplifier. The collector of transistor **42** is connected to a source of positive direct current which may be at a potential of 28 volts and the emitter of transistor **42** is connected to time constant detector **22**.

Time constant detector **22** which discriminates between an input signal having a fast rise time, indicating a short circuit in fire sensor **16**, and an input signal having a relatively slow rise time, indicating overheating of fire sensor **16**, is comprised of two parallel circuits connected between the emitter of transistor **42** and ground. The "short" branch of time constant detector **22** consists of a first resistance **44**, which may have a value of 10K ohms, in series with a second resistance **46**, which may have a value of 20K ohms. The "fire" branch of detector **22** consists of a resistance **48**, which may have a value of 10K ohms, in series with a capacitor **50**, which may have a value of 1 microfarad. The operation of this circuit will be explained in detail under the section entitled "Operation." The output of the "short" branch of time constant detector **22** is taken from the junction of resistors **44** and **46** and is applied to the base of NPN transistor **52**. Similarly the output of the "fire" branch of detector **22** is taken from the the junction of resistor **48** and capacitor **50** and is applied to the base of NPN transistor **54** which should preferably be the same type as transistor **52**. The emitters of transistors **52** and **54** are coupled to small positive bias potential and the collectors are coupled to the positive terminal of a direct current source through resistors **56** and **58** respectively, which may each have resistance values of 10K ohms. The collector of transistor **52** is coupled to the base of PNP transistor **60** which comprises a portion of "short" indicator **24**. The emitter of transistor **60** is connected to the positive terminal of a direct current source and the collector of transistor **60** is coupled to ground through an indicating device **62** which may be an indicating lamp having a 28 volt filament. The collector of transistor **60** is also connected to the anode of diode **64**, the cathode of which is coupled to the collector of transistor **54**.

The collector of transistor **54** is connected to the base of a PNP transistor **66**, the emitter of which is connected directly to the positive terminal of the direct current source and the collector of which is connected to ground through an indicating device **68** which may be an indicating lamp with a 28 volt filament. The collector of transistor **66** is also connected to the anode of diode **70**, the cathode of which is coupled to the collector of transistor **52**.

System test circuit **28** is comprised of a positive action double-pole double-throw switch with an "off" center position and a single-pole double-throw relay. As shown in FIG. 2, toggle **72** of the double-pole double-throw switch is connected to a positive terminal of a direct current source. The contacts associated with toggle **72** are connected together and to one terminal of the excitation coil of single-pole double-throw relay **74**, the other terminal of which is connected to ground. The moving contact of relay **74** is connected to center conductor **18** of the fire sensor **16** and the stationary contact of relay **74** is connected to ground so that upon excitation of relay **74** the center conductor **18** becomes grounded. Toggle **76**

of the double-pole double-throw switch is connected to the base of transistor **52** and the particular contact associated with toggle **76** and which represents the "short" test position remains disconnected while the other contact representing the "fire" position is connected to ground. Toggles **72** and **76** of the double-pole double-throw switch are mechanically connected together within the switch and may be activated manually whenever it is desired to test the circuitry of the fire warning system.

The pulse generator test circuit **30**, shown schematically in FIG. 2, is provided to sample the string of pulses **12** produced by pulse shaper **10** and to provide a "short" indication at indicator lamp **62** in the event that there is a malfunction of the pulse shaper **10** by either the failure to produce pulses of either positive or negative polarity, or the failure to produce pulses of sufficient amplitude. For this purpose, the pulse generator test circuit **30** samples the input from the center conductor **18** of the fire sensor **16** and, if pulse shaper **10** is properly operating, produces an output signal to the base of an NPN transistor **80**, the collector of which is coupled to the collector of transistor **52** in the "short" indicator circuit and the emitter of which is connected to a small positive bias source. As long as the base of transistor **80** is maintained as a negative potential with respect to its emitter, transistor **80** will be disabled and will produce no "short" output indication. However, should the base of transistor **80** become positive with respect to its emitter, a "short" indication will be produced.

In the embodiment illustrated, pulse generator test circuit **30** is connected to the center conductor **18** of fire sensor **16** through two back-to-back Zener diodes **82** and **84**, each of which may have a Zener voltage of 8.2 volts. An input signal, which must exceed this Zener voltage, is then applied to the cathode gate of a silicon controlled switch **86**, the cathode of which is connected to ground, and the anode of which is connected to the positive terminal of a 28 volt source through a resistance **88** which may have a value of 15K ohms. The anode of silicon control switch **86** is coupled through a capacitor **90**, which may have a value of .015 microfarads, to the cathode of a diode **92** and the anode of diode **94**. The cathode of diode **94** is connected to ground and the anode of diode **92** is connected to the base of transistor **80** and to a storage capacitor **96**, the other terminal of which is connected to ground. The base of transistor **80** is also connected to the positive 28 volt source through a resistance **98** which may have a value of 270K ohms.

Zener diodes **82** and **84** assure that only those pulses which exceed the Zener voltage will enter the pulse generator test circuit **30** so that if pulse shaper **10** is producing pulses of insufficient amplitude, there will be an indication on "short" indicator **62**. When pulses of sufficient amplitude are present, silicon controlled switch **86** will become conductive upon the occurrence of a pulse of a first polarity and will become nonconductive upon the occurrence of pulses of opposite polarity. Thus, silicon controlled switch **86** produces at its anode a square wave output having a frequency and pulse length determined by the string of pulses **12** produced by pulse shaper **10**. The alternating switching of the silicon controlled switch **86** produces a corresponding switching or charge on storage capacitor **96** and the repetition rate of this switching will maintain the base of transistor **80** slightly negative with respect to its positive emitter potential. However, should pulse shaper **10** fail to produce a pulse of sufficient amplitude or fail to produce a pulse of one polarity, the storage capacitor **96** would fail to charge or discharge and a positive DC potential would be applied through resistor **98** to the base of transistor **80** which would in turn activate the "short" indication circuit.

Pulse shaper **10** is schematically illustrated in detail in FIG. 3. It will be noted that the circuit is symmetrical; the circuit to the right produces positive pulses and the circuit to the left is identical but inverted and produces negative pulses. Since the two symmetrical circuits are identical and operate in the same manner, only the right circuit will be explained in detail. A resistance **100**, which serves as an isolation resistance and may have a value of 200 ohms, is coupled between a 400 cycle 26 volt power source and a storage capacitor **102** the other terminal of which is grounded. Storage capacitor **102** may have a value of 1.0 microfarad. The junction of resistance **100** and capacitor **102** is connected to the anode of a diode **104**, the cathode of which is connected to the collector of an NPN transistor **106**, a capacitor **108**, which may have a value of 0.1 microfarad, and a resistance **110** The second terminal of capacitor **108** is coupled to the anode of a diode **112**, the cathode of which is connected to the second end of resistance **110**. The junction of capacitor **108** and diode **112** is coupled through a resistance **114** to the base of a PNP transistor **116**, the emitter of which is connected to the junction of diode **112** and resistance **110**, and the collector of which is coupled through a resistance **117** to the base of transistor **106**. The emitter of transistor **116** is also connected to a capacitor **118**, which may have a value of 1.0 microfarad, the second terminal of which is coupled to the emitter of transistor **106**. The output of the circuit is taken from the emitter of transistor **106**, through an AC coupling capacitor **119**.

On the positive half cycle from the AC source, current flows through resistance **100** and begins to charge storage capacitor **102**. The current also passes through diode **104** to charge capacitor **108** and capacitor **118**. During this charging period the small voltage across the diode **112** maintains the base positive with respect to the emitter so that transistor **116** is nonconductive. When the AC voltage peak is reached and starts down, the diodes **104** and **112** are cutoff so that the charge on the capacitor **108** is applied as a negative potential to the base of transistor **116** becomes reduced with respect to the emitter thus rendering transistor **116** conductive. At this point the positive potential on the partially charged capacitor **118** is applied through transistor **116** and resistance **117** to the base of transistor **106**, suddenly rendering that transistor conductive. The fully charged storage capacitor **102** is then permitted to discharge through transistor **106** to the output terminals of the circuit.

During the negative half cycle of the AC source, the left portion of the pulse generator operates in the identical manner to produce a negative pulse having a very sharp rise time.

OPERATION

As previously noted, the pulse generator and shaper **10** produces sharp rise time pulses of both positive and negative polarity through the current detector **14** to the fire sensor **16**. If the fire sensor senses an actual fire, there will be a relatively slow increase in current sensed by the current detector **14**, and if there is a short circuit in the fire sensor system, there will be a relatively fast rise in current sensed by current detector **14**. These currents are rectified by bridge rectifier **20**, are amplified by the power amplifier **42** and applied to time constant detector **22** which has two output terminals respectively connected to the "short" indicator **24** and the "fire" indicator **26**. The "short circuit" branch of time constant detector **22** comprises two series resistances and the output therefrom is taken from the junction of these resistances which acts as a voltage divider circuit between the emitter of transistor **42** and ground. The "fire" branch of time constant detector **22** comprises a resistance and capacitor in series between the emitter of transistor **42** and ground and the output is taken at the junction of resistance **48** and capacitance **50**.

FIGS. 4 and 5 illustrate typical output curves of the time constant generator **22**. If a short circuit occurs in fire sensor **16**, there is a rapid increase in current and a consequent rapid conduction of transistor **42** and the output of the short circuit branch of time constant detector **22**, as illustrated in FIG. 4. Because of the time

constant of resistance **48** and capacitor **50** in the "fire" branch of the time constant detector, the "fire" output voltage will rise much slower, as illustrated in FIG. 4. In the event of an actual fire, current detector **14** will sense a relatively slow increase in current and the voltages appearing at the respective output terminals of the time constant detector **22** will appear as shown in FIG. 5. The two output voltages from time constant detector **22** are applied to their respective indicators which comprise transistors **52** and **54** and the circuitry associated therewith.

If a short circuit occurs in fire sensor **16**, the quicker rising "short" voltage appearing in FIG. 4 will be applied to the base of transistor **52** to render that transistor conductive. As transistor **52** draws current from the DC source through resistance **56**, the voltage appearing on the collector of transistor **52** is lowered and there is a corresponding lowering of voltage on the base of transistor **60**. This PNP transistor **60** is now rendered conductive and substantially the full DC power source voltage is applied across indicator lamp **62** to indicate that a "short" exists in the fire warning system.

When transistor **60** becomes conductive to apply the full source voltage across indicator lamp **62**, this same voltage is applied through diode **64** to the base of transistor **66**. This provides a lock-out feature so that any subsequent conduction of transistor **54** in the "fire" indicator system will draw collector current through diode **64** rather than resistance **58**. The result is that there will be no potential drop at the collector of transistor **54** or the base of transistor **66**, and transistor **66** will remain nonconductive.

In the event of an actual fire sensed by sensor **16**, the output voltages occurring at the terminals of time constant detector **22** will appear as shown in FIG. 5. During the slower rise of these voltages, the output from the "short" terminal of time constant detector **22** will be reduced because of the voltage divider action of resistors **44** and **46**. The "fire" branch will produce a voltage sufficient to render transistor **54** conductive and thus decrease the potential appearing on the base of transistor **66**. When transistor **54** becomes conductive, transistor **66** will conduct to apply the full source potential across indicator lamp **68**. This potential is also applied through diode **70** to the base of transistor **60** to render transistor **60** nonconductive.

As pulse shaper **10** produces its train of positive and negative pulses, these pulses are sampled by the pulse generator test circuit **30** through Zener diodes **82** and **84**. In the event that pulse shaper **10** fails to produce pulses of adequate amplitude or otherwise fails, pulse generator test circuit **30**, which has been explained in detail, will apply a positive voltage to the base of transistor **80** thereby rendering that transistor conductive so that it will draw current through resistor **56** to lower the potential on the base of transistor **60**, thereby rendering transistor **60** conductive to apply the full source voltage across indicator lamp **62**. If the pulse shaper produces low amplitude pulses due to low heat sensor resistance resulting from an actual fire, transistor **66** will be conductive and will supply the current to the collector of transistor **80** through diode **70**. Thus, an indication from lamp **62** may indicate not only a short circuit in the fire sensor **16**, but also a malfunction of pulse shaper **10**.

System test circuit **28** comprises a double-pole double-throw manually operated switch and a single pole single throw relay. If it is desired to test the operability of the fire warning system, a crew member may activate the manually operated switch to its left, or "short" position. This forces relay **74** to close and to ground the center conductor **18** of the fire sensor **16**. This grounding causes a rapid increase in current through the current detector and the time constant detector **22** will produce an output which activates the short indicator **24**.

If the manually operated switch is placed in the right or "fire" position, the base of transistor **52** in the short

indicator circuit **24** becomes grounded so that transistor **52** will remain nonconductive. With transistor **52** nonconductive, transistor **54** will become activated to produce a "fire" indication in indicator lamp **68**. The operability of the entire fire warning system may thus be accurately and rapidly tested at any desired time.

Having thus described the preferred embodiment of my invention, what is claimed is:

1. A fire warning system for use with a fire sensor for indicating both the presence of fire and a malfunction of the sensor and the fire warning system circuitry, and for curing fractures in an eutectic salt type of fire sensor, said fire warning system comprising:

pulse generating means coupled to the fire sensor for applying bipolar voltage pulses having steep wave fronts across the eutectic salt;

current detection means coupled for sensing the current flow produced by said bipolar pulses through the fire sensor;

time detection means coupled to said current detection means for producing first and second output signals, the first having an amplitude directly proportional to the amplitude of the current change and the second an amplitude gradually increasing at a rate proportional to the amplitude of the current change sensed by said current detection means; and

circuit means coupled to said time detection means and responsive to the output signals therefrom for activating a first indicator when the amplitude of the first output signal from said time detection means exceeds the second output signal and for activating a second indicator when the amplitude of the second output signal exceeds the first output signal.

2. A fire warning system as claimed in claim **1** wherein said time detection means includes a voltage divider circuit for producing an instantaneous output signal with limited amplitude and a time constant circuit for producing an output signal having a slower rise time and ultimately higher steady state amplitude than the instantaneous output signal.

3. The fire warning system, as claimed in claim **1**, wherein said circuit means includes lock-out means for disabling the first indicator upon activation of the second indicator and for disabling the second indicator upon activation of the first indicator.

4. A fire warning system, as claimed in claim **1**, wherein said current detection means comprises a current transformer, the primary windings of which are coupled in series between said pulse generating means and the fire sensor.

5. A fire warning system, as claimed in claim **1**, further including a rectifier and amplifier coupled between said current detection means and said time detection means.

6. A fire warning system, as claimed in claim **1**, further including pulse testing means coupled to sense the repetition and the amplitude of the bipolar pulses produced by said pulse generating means said testing means producing a signal for activating an indicator upon malfunction of said pulse generating means.

7. A fire warning system, as claimed in claim **1**, further including system testing means coupled to the fire sensor and to said circuit means for causing an increased current to be sensed by said current detection means and the consequent activation of an indicator.

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